ILE COPY FOREST INSECT LABORATORY, STANFORD UNIVERSITY CALIFORNIA.

532.11
~~530~~
Manuscript MS
Isolate

roposed Title - BARKBEETLE ATTACKS IN PINE FORESTS OF THE PACIFIC SLOPE REGION.

By J. M. Miller

Agencies Causing Dead Timber in Pacific Slope Forests.

An inventory of the forest resources of the Pacific Slope region must take into a ount the dead timber, either standing or down which occurs everywhere througout the virgin stands.

This dead material varies greatly in quantity and the percent which it compoes of the entire stand. In a few localities, it has accumulated as a result of the rapid killing of nearly all trees within a comparatively short period of tie.

Where such conditions exist, they are normally due to heavy fires or to insect epidemics of the more virulent type. But dead trees also occur within a stand which is apparently healthy. Occasional dead and dying trees, or groups of trees may be found here and there throughout a forest, in all other respects green and thrifty. While the seriousness of the condition caused by these occasional dead trees, is frequently disregarded, it involves, in the aggregate, the loss of many millions of board feet annually. By far the greater part of the loss caused by insects in North American forests, is due to killing of mature trees scattered irregularly throughout stands that are otherwise in a healthy condition.

The tree killing agencies of Pacific Slope Forests are generally recognized in the order of their importance, as fire, insects, disease, lightening and storms. Insects have been placed next to fire in importance by a leading authority on American Forestry.* Other authorities have placed insects just as a destructive agent in the relative amount of timber killed. The relative importance of these two agencies in forest protection is still a matter of some controversy. Varying estimates have been made of the actual amount of timber killed by each cause, but on the whole comparative figures other than broad estimates are available only for a few local areas. The interrelation of insects and fires is a subject leading

* H. S. Graves.

into many of the debatable phases of forest protection, but on this subject as well, very little detailed and specific data has been presented. The present paper however does not attempt to enter into any of these subjects which are closely related to Forest Entomology, but is confined entirely to observations of those features which show how forest insects operate in their attacks upon living forests and the ultimate effects of these attacks as shown by conditions in the Pacific Slope region.

Infestation in Pine Stands.

Of recent years the attention of practically all insect control work has been directed to the situation in the pine forests of the west, due to the killing of merchantable trees by a few species of barkbeetles. Other insects there are injuring and to some extent killing trees in the vast forests of fir, spruce, hemlock, ceder and redwoods, but the economic importance of the forest insect situation has not, at least, brought forward any organized or concerted effort upon the part of interested owners to control insect damage in any species of timber except pine.

All observations show that western yellow pine, considered in the light of its commercial rating and the amount of loss to this species resulting from insect depredations, takes first rank in importance as a host tree and in the problems arising from its protection. In the northern and northeastern part of the Pacific Slope region the mountain pine beetle appears to be paramount as a tree killing agent of this species. Throughout Southern Oregon and California however, it has been well established that the western pine beetle is primarily responsible for the timber killed and that this insect must be considered first in control operations.

Sugar pine and western white pine are killed largely by the mountain pine beetle, and these two species may be said to rank next in importance, from an insect control standpoint, because of the high quality and value of their lumber, although the aggregate loss does not approach that which occurs in yellow pine. Jeffrey pine also is killed by the Jeffrey pine beetle peculiar to this host tree, but the limited distribution of the tree does not bring it into prominence. Lodgepole pine where it occurs in pure stands, is frequently subject to virulent epidemics of the mountain pine beetle which kill practically all trees over great areas. But this tree has as yet developed little, if any, commercial value and no effort has been made to effect its protection except for its value to the National Parks, watershed protection and to protect adjacent stands of more valuable species. Other insects besides Dendroctonus beetles also kill pine, some of which have developed importance locally, but in any general survey of the insect control situation it is not beleived that extensive problems will develope outside of these species.

Evidence of Insect Killed Timber Not Recent

The cause and character of forest insect losses is a subject regarding which a great deal can be said without arriving at any reliable conclusions. The very nature of the field lends itself readily to scientific speculation as the effect of insect depredations upon forests are cumulative and cannot be determined by the observations of one season. Tree killing insects infest trees during the period while the tree is dying and for a brief period only after the tree is dead. For this reason, the cause of much of the insect killed timber must be determined be indirect evidence. Foresters and Lumbermen alike have been slow to attach much importance to the loss caused by forest insects and it was some years after the first warnings by the leading forest entomologist* of this country before any serious interest was manifested in the conditions which he pointed out.

Only within very recent years have any detailed and consecutive observations been kept within the Pacific Slope region to show annual increase or decrease in the quantity of insect-killed timber. We have little, if any historical data to show that the insects enemies which now infest the present stands were present and operated in like manner in past decades. If the infestation which is now developing, is only of recent origin and a new factor in the situation, there is no assurance but that it may increase to a point where the entire stand will be threatened, and failure to effect measures of repression will result in the killing of the greater part or all of the magnificent forests upon which this country now depends, not only for the supply of its finest lumber, but also for watershed protection and for recreative possibilities. If on the other hand, insects which are now killing the trees are composed of species which have existed since the beginning of our present forests, if periods of increase in insect damage have been followed by periods of decrease, and if the trees that stand today have grown and developed to their present dimensions and density of stand regardless of the constant presence and recurrent attacks of these insects, then we cannot expect an average loss greatly exceeding that which is represented by the insect killed timber which exists in stands at the present time. The entire policy of protection against forest insects must be based upon an interpretation of existing conditions in the light of what has occured in the past under similar conditions of attack by the same species of insects.

---

*Dr. A. D. Hopkins - Bull. No.58, Part V, Insect Depredations in North American Forests and Practical Methods of Prevention and Control.

Fortunately there is some evidence upon which we can rely to determine the cause of insect killed timber even for some years after it is dead. Certain marks on the trunk and exit holes in the bark are characteristic of the different species of bark beetles. Unless destroyed by fire or decay, these marks will persist for a number of years after the tree has been abandoned by the beetles. By means of this evidence we have been able to get a few authentic records extending back of the past decade. One case is that of a witness tree to a section corner on the Klamath National Forest. This tree was scribed by the U. S. Land Office survey in 1880. The tree later had been killed and the bark and trunk showed unmistakably that this had resulted from the attack of the western pine beetle. The number of growth rings indicated that the tree was killed seven years after it was scribed as a witness tree, or in 1887. This evidence however only established the presence of these insects in that locality thirty years ago. (See photo-#20) Other evidence of old insect depredations in this region extending further back than this comparatively short period is largely conjectural. Old insect-killed timber is frequently seen but the exact period of the insect epidemic which produced this killing can only be approximated. The evidence however points generally to the fact that insects have been at work in these forests for many years back of the time that we have any authentic records.

But in the absence of any authentic records we may still resort to detailed studies of the character of insect epidemics to determine whether the conditions that exist in our forests today can be accounted for under the normal influence of similar ~~insect infestation~~ epidemics in the past. Such observations must necessarily cover a period of several years.

Just how the conditions in our present forests have been brought about cannot be determined by the examinations of one season. An examination conducted for a brief period only may show a preponderance of abandoned and recently killed trees, with very few infested trees indicating an apparent decreasing condition of the infestation. At another season it may be found that the proportion of infested trees is so great as to give convincing evidence that the barkbeetles are increasing. These two opposite conditions may be found at the same time in widely separated areas. This indicates that infestations may pass through periods or cycles of increase and decrease, beginning possibly, with a very small amount of infested timber, increasing to a maximum and then declining. If this is the case then the records covering only a brief part of one season, will throw but little light upon the true character of the cycle. The result is similar to a record of a freshet taken from one reading of the watergauge; the normal stream flow, the high water mark and the period of ~~the~~ time involved in the rise and fall, are still unknown quantities. In the case of barkbeetle epidemics, records must be kept consecutively through a period long enough to cover the entire cycle before the nature and character of this class of infestation can be understood.

History of Epidemics in Southern Oregon and Northern California.

It was with the view of obtaining some data upon this most important phase of the forest insect control problem that the Bureau of Entomology began the detailed study of the infestations within definite areas located in Southern Oregon and Northern California. This study was conducted through the Field Station located at Ashland, Oregon, and the first observations which were started included the field season of 1915. A detailed organization of the surrounding territory was effected as a basis for the subsequent observations. The area consisted of parts of the three main watersheds of the region, the Rogue, Applegate and Klamath Rivers.

Area	Average.
Rogue River - - - - - -	89,100
Klamath - - - - - - -	255,700
Applegate - - - - - -	200,000

544,800

Each of these main watersheds was subdivided for the purpose of the study, into smaller areas which were termed infestation units. So far as possible, these units were determined by natural drainage features and usually consisted of the watersheds of tributary creeks. In size these varied from 7,000 to 55,000 acres, although a few smaller units were arbitrarily defined for the purpose of intensive studies. As a rule, these units represent in size and character, the area which is ordinarily included in a control project.

General Conditions.

The stands included in the area covered by this study are fairly representative of the forest donditions throughout the region. Western yellow pine composes about 40% to 50% of the stand and is the most valuable timber species involved in the project. Sugar pine occupies a varying percentage of the stands, but except on a few units it is relatively small in amount. Douglas fir composes

composes a large percent of the forests but no important insect damage was found to have developed in this as a host tree. Some damage, primarily attributable to insects, was found in the Douglas fir but the work was almost entirely concentrated upon the more important situation due to the killing of the mature yellow pine and sugar pine timber by Dendroctonus beetles. Field records were started in the summer of 1915, and the entire project area was organized and completely covered by reconnaissance during the Spring of 1916. The entire period for which records have been secured covers the seasons of 1914, 1915, 1916 and 1917. Intensive studies were located upon the Rogue River Area and, as 60% of this area was intensively cruised and all trees marked, numbered and recorded, the data secured are considered to be as accurate as can possibly be obtained by any method of field examination. A form record was kept of the data for each tree that was marked and subsequent examinations were made of a number of trees in order to note the developement of the insects and deterioration of the tree. The remaining 40% of the Rogue River Area and also the Applegate and the Klamath Areas were examined by methods of extensive reconnaissance with occasional intensive plots as a check upon the field data.

It was considered that the Rogue River Area afforded the best conditions for the study of the developement of an epidemic under natural conditions, undisturbed by attempted control work or artificial measures, such as lumbering operations. This Area includes the forests on the western slopes of the Rogue River Valley from the head of Bear Creek to Gold Ray Dam and the timber forms a long narrow belt along the western slopes of the Rogue River Valley. The infested area was bounded on the east by the open Rogue River Valley varying in width from two to twelve miles. On the south and west the infestation is broken by the Siskiyou Divide and the Rogue River-Applegate Divide. There is no distinct boundary to the north and the area was arbitrarily terminated where the infestation in pine became so slight that it is scarcely appreciable. There are no records of infestation on this area earlier than 1913. Inthe winter of 1912 and 1913, Mr. Edmonston, of this bureau, located all told about six or eight infested yellow pine trees in the vicinity of Ashland. There was no appreciable increase during the season of 1914, although several lightening struck trees were found infested by the western pine beetle and a few trees were found which had been entirely killed by this insect. The loss in 1914 as determined by subsequent examinations amounted to 409,770 board feet.

In the spring of 1915, it became evident that there was a considerable increase in the amount of yellow pine which was being killed. During the fall of 1915, fading and red-topped trees began to appear all over the area. A noticeable feature of the damage during 1915 was the predominance of top-killed trees which were found to be caused by attacks of the engraver beetle (Ips confusus). Insects killed 1,719,500 board feet of merchantable timber during 1915, in trees ranging from 12 inches D.B.H. to 60 inches D.B.H. This amounted to 1.09% of the total stand of pine and indicated an increase of 319% over the loss of 1914.

During the early part of the summer of 1916, there was nothing to indicate a decrease in this epidemic. Following the spring emergence from overwintering trees attacked in the fall of 1915, hundreds of new trees were attacked in the spring and early summer of 1916. It appeared that the epidemic was still increasing and the loss for 1916 would be greater even than for 1915. However, in all units, the infestation took an entirely different turn in the fall of 1916. There was a great falling off in the number of trees which were attacked this fall as compared with the fall of 1915, although, in some cases, the number of trees attacked early in the summer of 1916, was so great that the annual loss equaled or exceeded that of 1915. In the summer of 1917, following the decline which had started in the fall of the previous year, it became quite evident that trees of the 1917 generations scarcely exceeded the number of those which had been killed in 1914. Apparently the epidemic had run its course in two years. The epidemic of the engraverbeetle in the top-killed trees disappeared in the spring of 1916 almost as suddenly as it appeared in the fall of 1915. The loss as it was recorded according to generations and species of beetles and seasons is shown in the following table.

Chart of Rogue River Area.

This table brings out in a quantitative way, that the western pine beetle (D.brevicomis) was the primary forest enemy of the pine timber of this region. The loss caused by this species approximates 90% of the entire loss from all causes. The loss caused by the mountain pine beetle (D. monticolae) to sugar pine, ranks next in importance. An engraver beetle, (Ips confusus) which kills small trees in pole stands and the tops of older mature trees, ranks third in importance.

A still further source of loss occurs in trees which die from causes which could not be determined within the limits of this study. This has sometimes amounted to as much as 3.7% of the total annual loss. It was definitely determined that insects were in no way responsible for this class of loss, but no effort was made to determine the primary cause which may have been disease or some pathological disturbance.

In the endemic or quiescent dondition of the enfestation, in 1914, the loss involved on the entire area amounted to a little more than two tenths of one percent of the total pine stand. During the next year, when the more acute period of the epidemic developed, this loss increased to nearly one and one tenth percent of the pine stand for the total area. This represented the average maximum percent of loss for the entire area. The percent of loss varied to some extent on the individual units, the maximum ranging from seven tenths of one percent to three and five tenths percent. The period from the time that this epidemic started until it reached its minimum of decline covers three years.

The loss caused by D. monticolae and Ips confusus during this period varied but did not apparently follow the cycle of the D.brevicomis epidemic. On

On both of the adjoining areas of the Klamath and Applegate watersheds which were studied during the same period by the general reconnaissance method, similar epidemics occurred, which followed practically the same cycle as that on the Rogue River.

On the Klamath Area the epidemic started in 1915 and the loss resulting from the attack of that year increased 240% over that of 1914. In 1916 it declined about 66% from 1915. The final data for the season of 1917 is not yet available, but it shows a still further decrease. The data is given in the following table:

It is shown that the percent of pine stand killed is considerably lower than on the Rogue River Area which is probably due to the fact that on much of the Klamath Area the epidemic developed at lower elevations in poor quality yellow pine while large bodies of sugar pine which grew at the higher elevations were but little effected.

On the Applegate Area, which was studied as a check, the infestation was entirely in yellow pine and in a quality of timber which is hardly considered merchantable. As no estimates of stands were available, the percent of stand killed was not determined. The cycle on this area is shown by the following table:

This in a general way, covers the history of an epidemic, which resulted in the killing of twelve million feet of pine timber on 545,000 acres in Southern Oregon and Northern California. Probably the most important result brought out by the investigation is the fact that the epidemic developed in about the same manner over the entire project area. Nowhere on the area did the epidemic on any unit or even that of any small center of infestation run contrary to the general trend of the epidemic throughout the area. Outside the limits of the territory covered by the project observations were not of a character to warrant general conclusions in regard to the increase or decrease of infestation.

It is shown however that, taking the project area alone, the conditions which brought about the rise and decline of the epidemic studied, extended over extensive areas and were not confined to small local units or centers.

Further evidence to this effect, was furnished by a survey of conditions in the Southern Sierra Region of California which was conducted co-operatively by the Bureau of Entomology and Forest Service. This survey covered the pine belt on the western flank of the Sierra Nevada Mountains from the Rubicon River as far south as the South Fork of the Tule River and involved the examination by extensive reconnaissance of over 19 billion feet of pine timber. It was found that throughout the southern part of this area, in the watersheds of the San Joaquin, King's, Kaweah, Tule and Kern rivers the infestation everywhere was in an epidemic and increasing condition. The area involved amounted to 800,000 acres, or practically all of the pine belt from the San Joaquin River south. North of this line the infestation was in an endemic and apparently declining condition, and the extent of the territory effected by this condition corresponded to that which was found to be involved in epidemics.

The periods covered by the epidemics recorded in this survey could not of course be determined by an examination of this kind. It was determined however, that during 1917 the western pine beetle killed during the season seventeen million feet of yellow pine timber, 60% of the loss occuring on the epidemic areas. The mountain pine beetle in sugar pine was responsible for the killing of ten million feet in 1917, averaging 35% of the total annual loss and was a far more serious factor than on the Rogue River Area.

Epidemics in Lodgepole Pine.

Of a different character from the epidemics of the western pine beetle in yellow pine or the mountain pine beetle in sugar pine are the more virulent mountain pine beetle epidemics which occur in the pure stands of lodge pole pine. These develop rapidly and result in the killing of a heavy percent of the stand within a period of five or six years. An example of this, for which we now have some records, occurred in the stands of lodgepole pine in the vicinity of Paulina Natural Forest in Eastern Oregon.

This epidemic started in 1909 and subsided in 1914. During this period, it killed 50% to 70% o lodgepole pine, but stopped at this point and did not spread into the surrounding stands of yellow pine. In sections of the Tuolumne River watershed in California, lodgepole pine has been killed to the extent of 90% of the stand where some years ago mountain pine beetle epidemics were prevalent. Because of the very low commercial rating of lodgpole pine the epidemics are of far less importance than the much milder ones which occur in yellow pine and sugar pine.

Significance of Barkbeetle Epidemics.

The history of the barkbeetle epidemics which have been studied indicate that the natural factors have maintained a balance of control sufficiently adequate to hold the depredations of these insects within certain limits. Were there no natural agencies to check or control barkbeetle epidemics, they would rapidly increase to the point where the extermination of the host trees would be a matter of a comparatively short time. Under normal conditions, nature provides for the prolific reproduction of these insects. Each individual may develop a progeny which amounts to an increase of many fold each season and were it possible for the progeny of each succeeding generation to develop and successfully attack new trees, the ultimate disappearence of the living forests would soon result. Locally this has actually occurred in a few instances, in the yellow pine stands of the Black Hills and the lodge pole stands in various sections of the country. Barkbeetle epidemics lasting through periods of several years have been the cause of enturely dead forests. Such conditions however, are the exception and not the rule.

By far the greater part of the iensect losses in the west develop from attacks similar to the one on the Rogue River Area which has been described. The progress of these attacks is not marked by a steadily increasing advance in the amount of dead timber, but by sharp intermittent cycles of increase and decrease. Even at the maximum of these epidemics, the amount of timber killed in anyone year seldom exceeds 2 percent of the stand and in the endemic period of the cycle the loss is less than two tenths of one percent of the stand.

The reasons for this can be better understood when we realize that the forest insects with which we are concerned are indigenous and have undoubtedly existed within the range of their present distribution far back of the time that we have any established records. During this time they have been obliged to maintain a constant defensive against their own natural enemies and the forces which contribute to their destruction, and only occasionally are they able to take the offensive and develope an attack in sufficient numbers to seriously threaten the existence of the forest. This condition was stated by Dr. A. D. Hopkins in 1909 as follows:

"These natural factors in the control of the depredating insects consist of parasitic and predatory insects, diseases of insects, birds, adverse climatic conditions, etc. While one or more of these beneficial factors exert a continuous and powerful influence toward the prevention of a more extensive waste of forest resources, it has been repeatedly demonstrated that they can not be depended on to prevent widespread devastations or to otherwise work for the best interests of the private or public owner by protecting the best trees and the best tree species. The insects and birds which prey upon the depredating insects also have factors to contend against, consisting of insects, birds, diseases, and climatic conditions. Therefore under normal conditions the tendency is toward the preservation of a ballance between the warring factors, but frequently the enemies of the trees get the ascendancy and take on the character of an invasion, which may continue for two or three or even ten years before ballance is again adjusted through the influence of the natural enemies or diminished food supply. Thus a vast amount of timber or of a given forest product may be destroyed before the factors of natural control can prevail".

Relation of Epidemics to Character of Stand.

It has been observed that to a great extent the type of epidemic which developes depends upon the type and character of the stand and the species of infesting insects. In pure stands of yellow pine and specially lodgepole, or mixed yellow pine and lodgepole, heavy epidemics may develope which during a cycle of five or six years may kill from 35% to 80% of the entire forest. Such epidemics always result from barkbeetles of the mountain pine beetle type. In mixed stands, such conditions rarely if ever occur. Throughout the commercial forests of California and Southern Oregon, we find a mixture of species with varying proportions of yellow pine and sugar pine, and almost everywhere mixed with other conifers such as white fir Douglas fir, incense cedar etc. In these forests, we have yet to record the advent of an epidemic that killed more than 3% of the stand in one season. The western pine beetle has been found to be the agent responsible for destruction of nearly all of the ensect killed yellow pine and the mountain pine beetle attacks sugar pine, developing a slow type of epidemic quite different from that which occurs in the pure stands of lodgepole in the same region or in yellow pine stands of the Rocky Mountain Region. The loss of both yellow pine and sugar pine which accumulates results from epidemics similar to those described on the Rogue River Area and involves even at the maximum a very slight percent of the stand annually.

How Slow Epidemics Deplete the Stand.

It would be a very easy matter to minimize the importance of the loss resulting under these conditions where the balance is almost continually maintained or where epidemics are so short lived that there is little apparent danger of the ultimate killing out of the host tree.

The age of the mature pine stands is variously estimated at from 300 to 400 years. Probably a maximum commercial rotation could be placed at 300 years. On this basis a loss not exceeding three tenths of one percent annually would be gradually replaced by the new growth coming on. On this basis the stand would maintain its present volume indefinitely.

A loss exceeding this, averaging, say 1% annually, would result in a slow but gradual depletion of the stand. This has actually occured to a noticeable extent in some localities, notably in certain districts in Southern Oregon and Northern California. The mature yellow pine and sugar pine trees have been killed faster than they could be replaced by normal growth with the result that we find a very pronounced opening of the stand in many places. A heavy growth of brush usually usurps the soil before a natural ~~stand of~~ reproduction comes in. This results in stand composed of green trees with many insect-killed trees, and a rapidly increasing undergrowth of brush (See photos P. 18 and 19). Such conditions can be observed to best advantage where no fires have occured for a number of years. Fires on account of the great amount of inflammable material burn out all of the old evidence of insect damage.

These conditions just described frequently become most severe at the lower elevations and on southern exposures where conditions favor developement of the beetles. While fire alone or insects and fire combined may accomplish the almost complete disappearence of forest cover on such areas, it is also evident that insects alone may accomplish the same result by the continual maintainence of this form of attack.

Regardless of the low rate of annual loss resulting from epidemics of the mixed stand type, this is now generally recognized as one of the most serious problems in forest protection. By far the greater part of the commercial pine timber in the west, exists in stands of this character. Of the $55,000 which has been spent on insect control work by public and private owners in California, practically all has been spent in the control of epidemics which did not exceed in intensity that which has been recorded on the Rogue River Area. This is so ~~true~~ because the toll taken by the insects comes from the larger mature trees in the stand. Were this relatively small loss distributed throughout all age classes, its effect would fall much more lightly upon the forest cover. But while it may be said that the matured trees killed are compensated by younger trees which grow up to replace them, it must also be granted that this loss represents trees which have required from 300 to 400 years for their production. Whether a forest is protected for its purely commercial value in our private holdings and National forests, or for its esthetic and sentimental value, in our National Parks, the killing of such trees represents the loss of an asset which cannot be replaced except by the growth of new trees which require from two hundred to four hundred years to reach similar dimensions. In commercial forests the mature trees of this class furnish the finest quality and grade of lumber that the stand produces. Upon the National Parks, it is the presence of these fine old forest veterans that adds greatly to their value and attractiveness as a national play ground. The cost of protection accumulates from year to year and ~~it is~~ only by the preservation of the trees that now exist, and not the production of new stands to replace the mature trees of the present forests, can a return be realized upon the investment represented by existing forests. This is the evident justification for control work even of the epidemics which may be classed as endemic and which are killing only a small percent of the stand. For every dollar invested in control it is only reasonable to expect an equal return in the value of the timber which is protected, and the control of epidemics must in the end be accounted for on this basis.

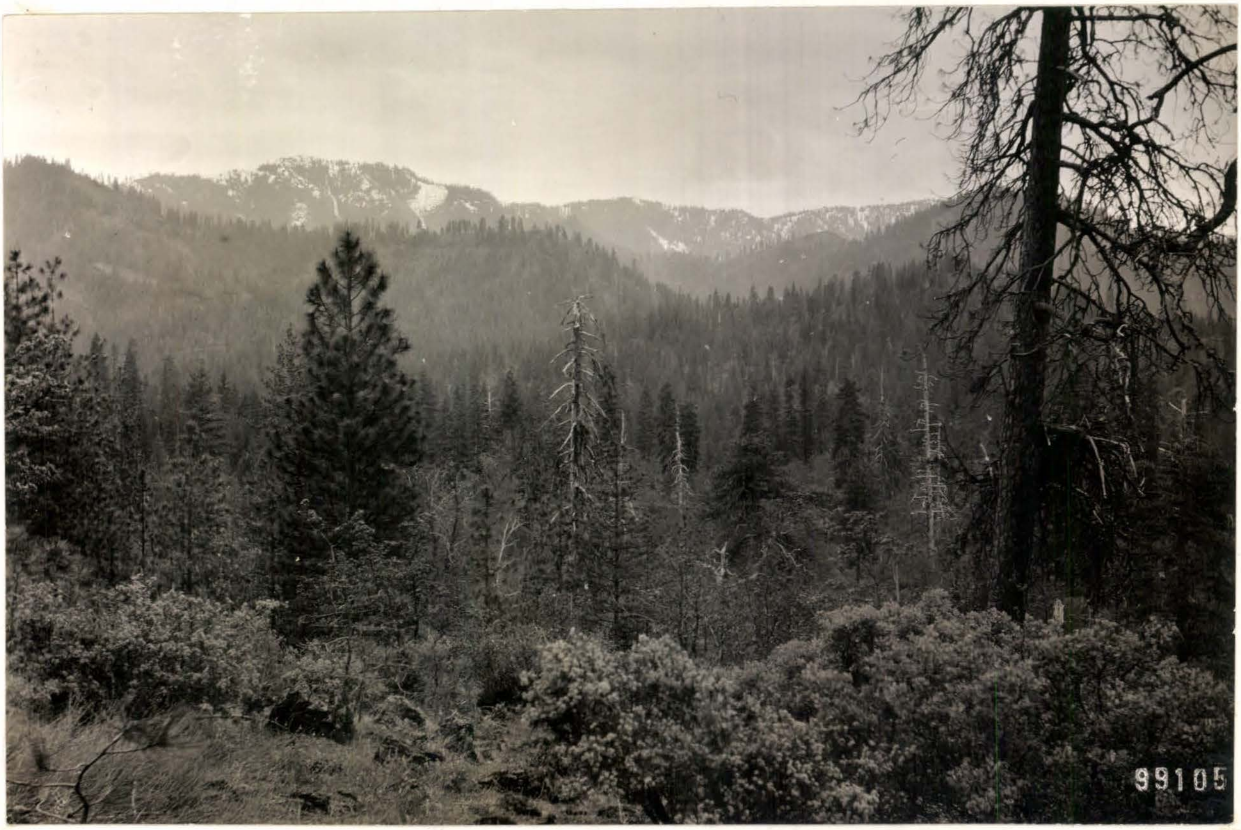
Methods of Control Based Upon Natural Factors.

All of the species of barkbeetle which up to the present have developed epidemics in western forests are indigenious. They have existed for many years within the limits of their present distribution, and the forests that stand today have grown up under the continual menace and recurrent attacks of these tree destroyers. In this respect forest entomology differs from other branches of applied entomology in America. Horticultural insects develop under artificial conditions within plantations that have been grown within the history of the agricultural settlement of the region. Furthermore the problems involved are limited to the narrow confines of the cultivated districts. On the other hand, there is every reason to believe that forest insects have existed far back of the time that we have any established record, and their distribution covers not small orchards or cultivated districts, but vast areas of forest lands extending over many thousands of square miles of territory.

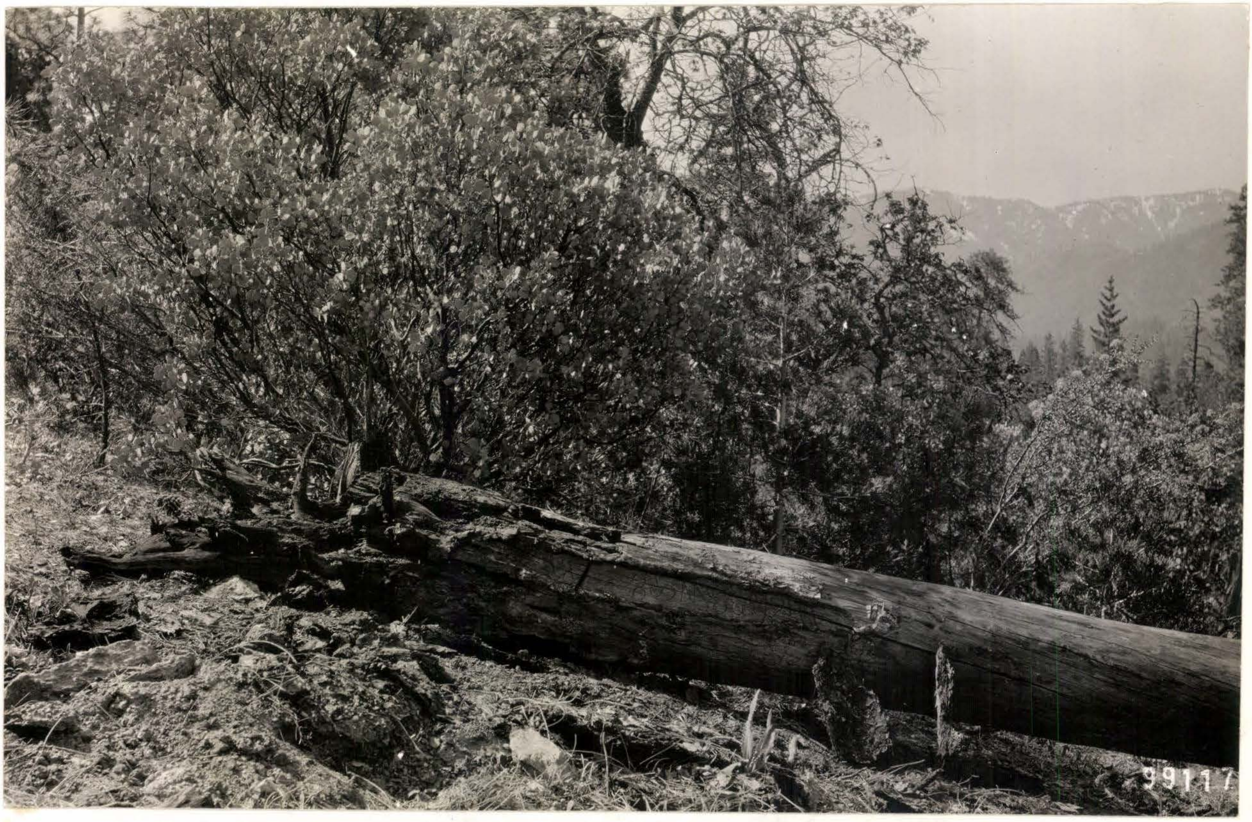
For these reasons it is evident that any policy of insect control to be sound must recognize and utilize the natural forces which govern the activities of forest insects and maintain the balance which exists between existing forests and their insect enemies. This is the basis for the percentage principle of control.

F.S. 99108.

Yellow pine killed by the western pine beetle on the Klamath National Forest, California. The dead trees are accumulating as the result of recurrent epidemics. Note the depletion of the stand which results from these slow but presistent attacks.



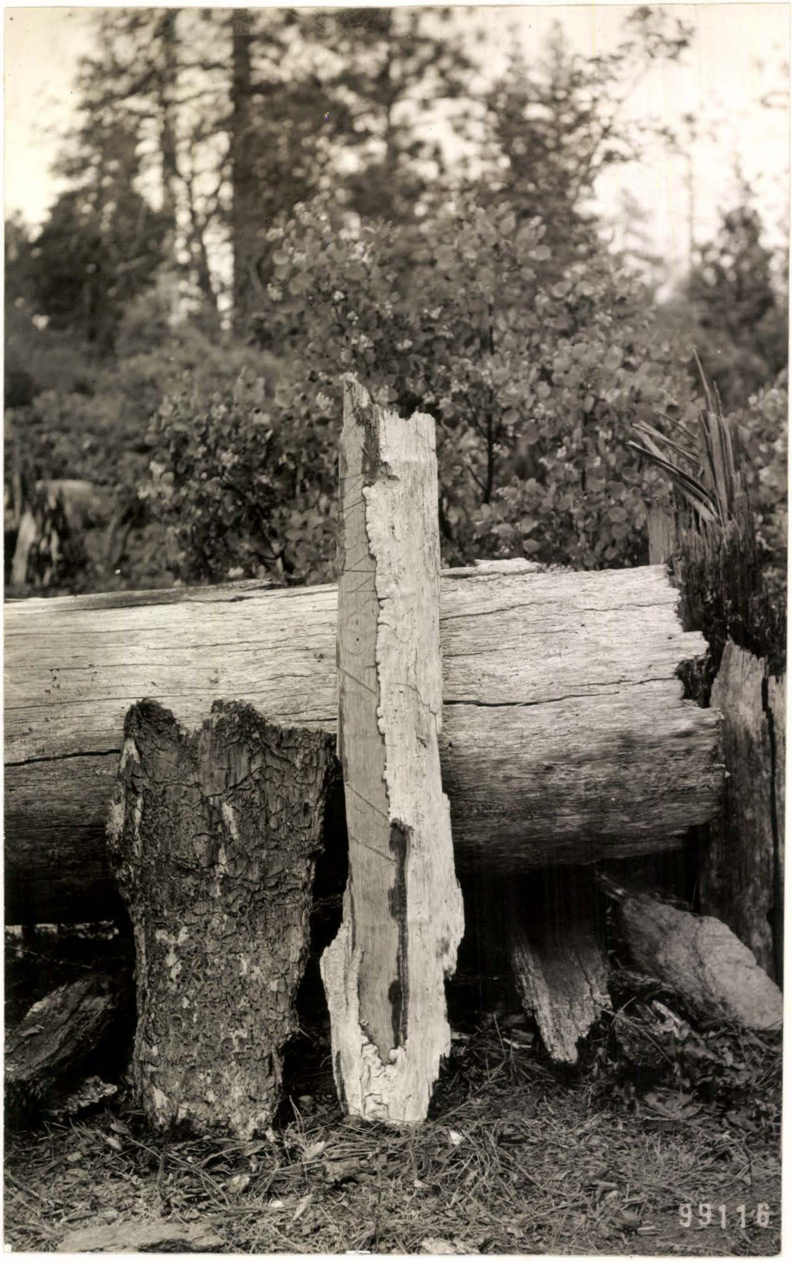
Dead yellow pine trees appearing throughout the stand as the result of western pine beetle attacks. While the insect-killed trees are scattered the amount of loss which occurs in this way amounts in the aggregate to many thousands of feet annually.



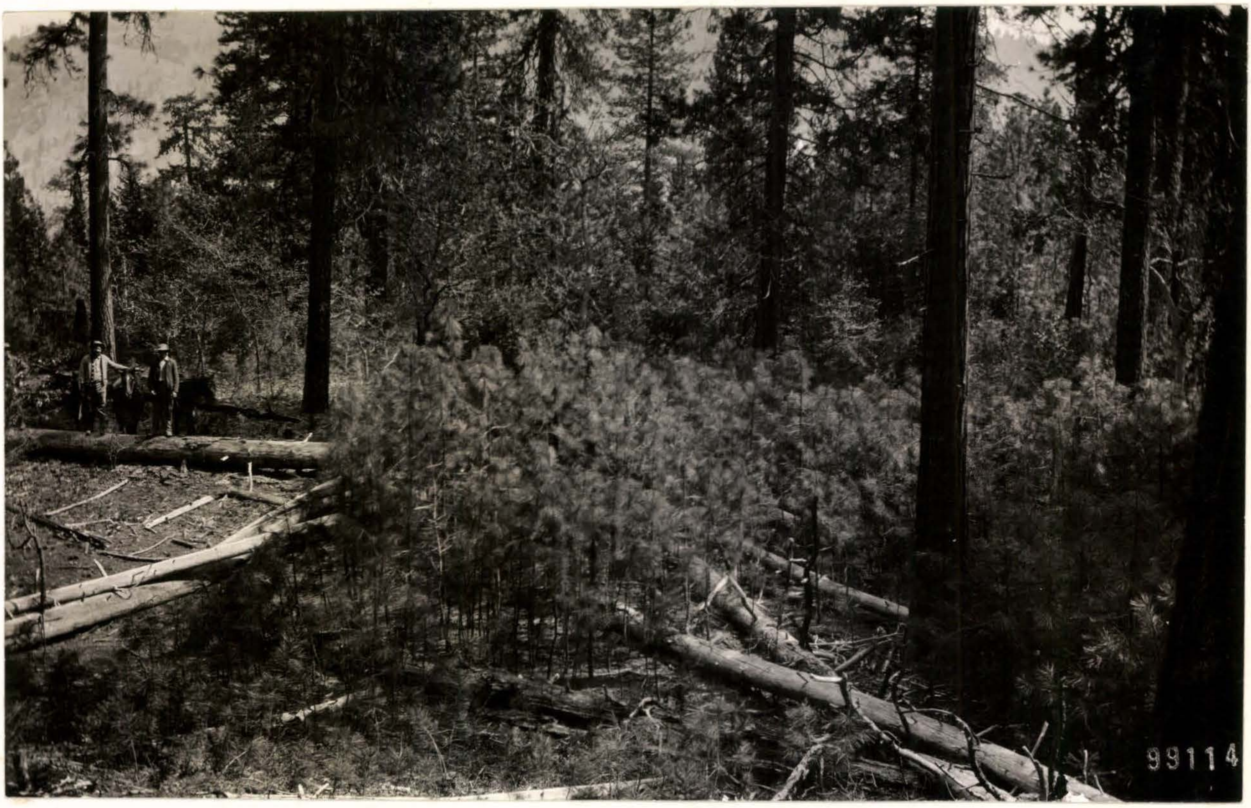
A witness trees to a section corner established by the U.S.Land Office survey in Siskiyou county, California. This tree was standing and green when it was scribed as a witness in 1878, but soon afterwards was attacked and killed by the western pine beetle. By counting the annual rings since the scribe it was determined that the tree was attacked in 1880.

2

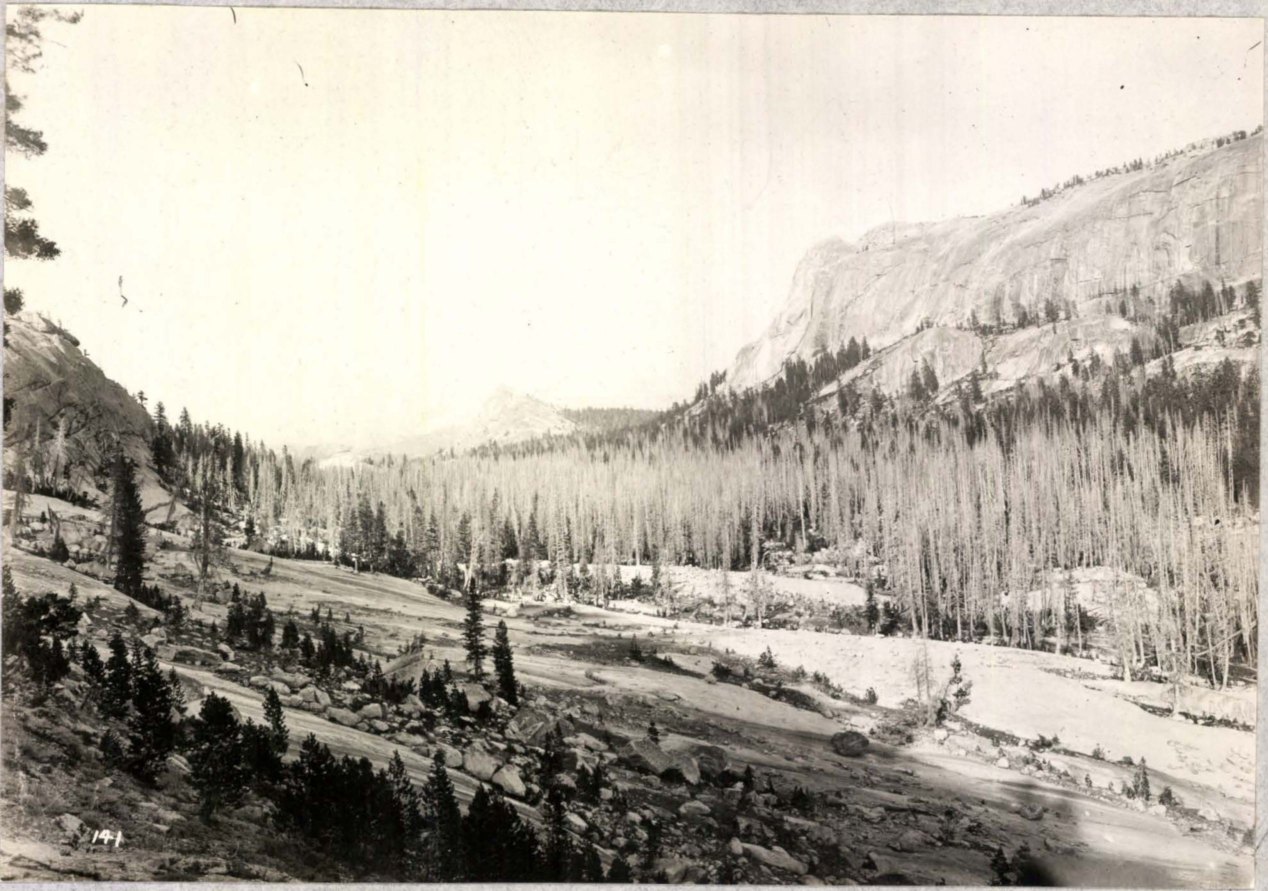
2



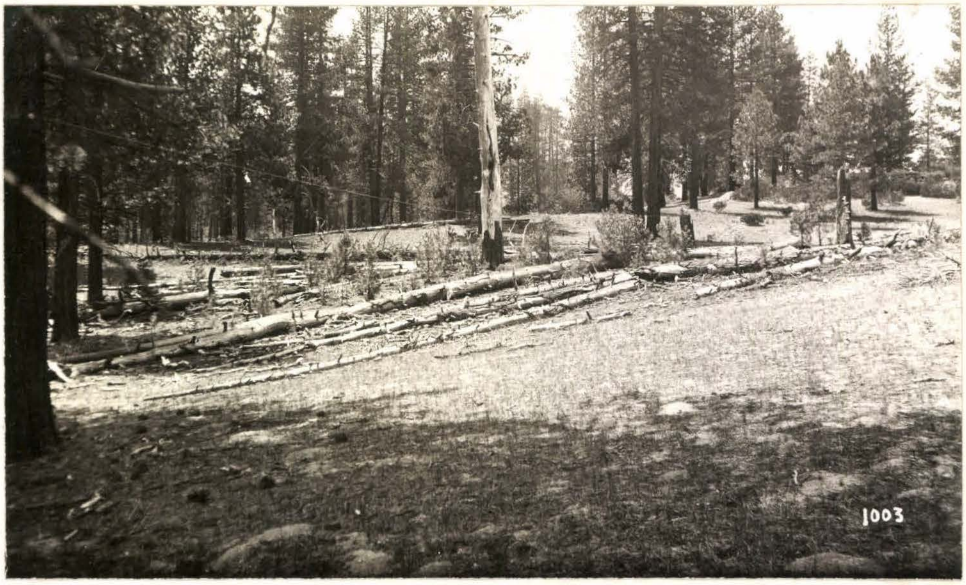
The remains of a witness tree to a U.S.land office section corner. Fragments of the bark which were found show unmistakably that the tree was killed by the western pine beetle. It was determined that it was attacked about 1884. 2/1

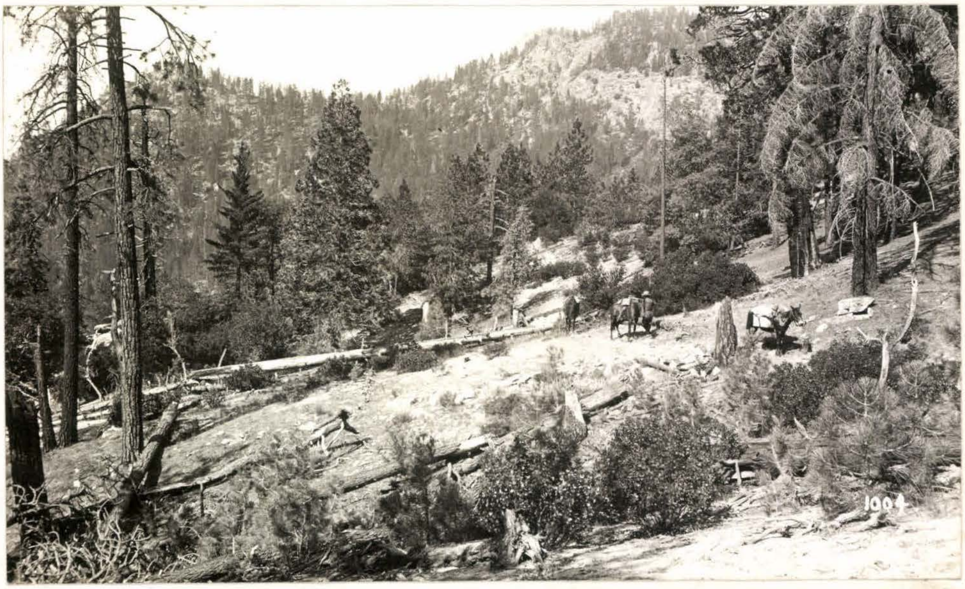


Young growth yellow pine coming into an opening of the forest caused by killing of mature trees by the western pine beetle. This shows insect loss may eventually be replaced by new growth.

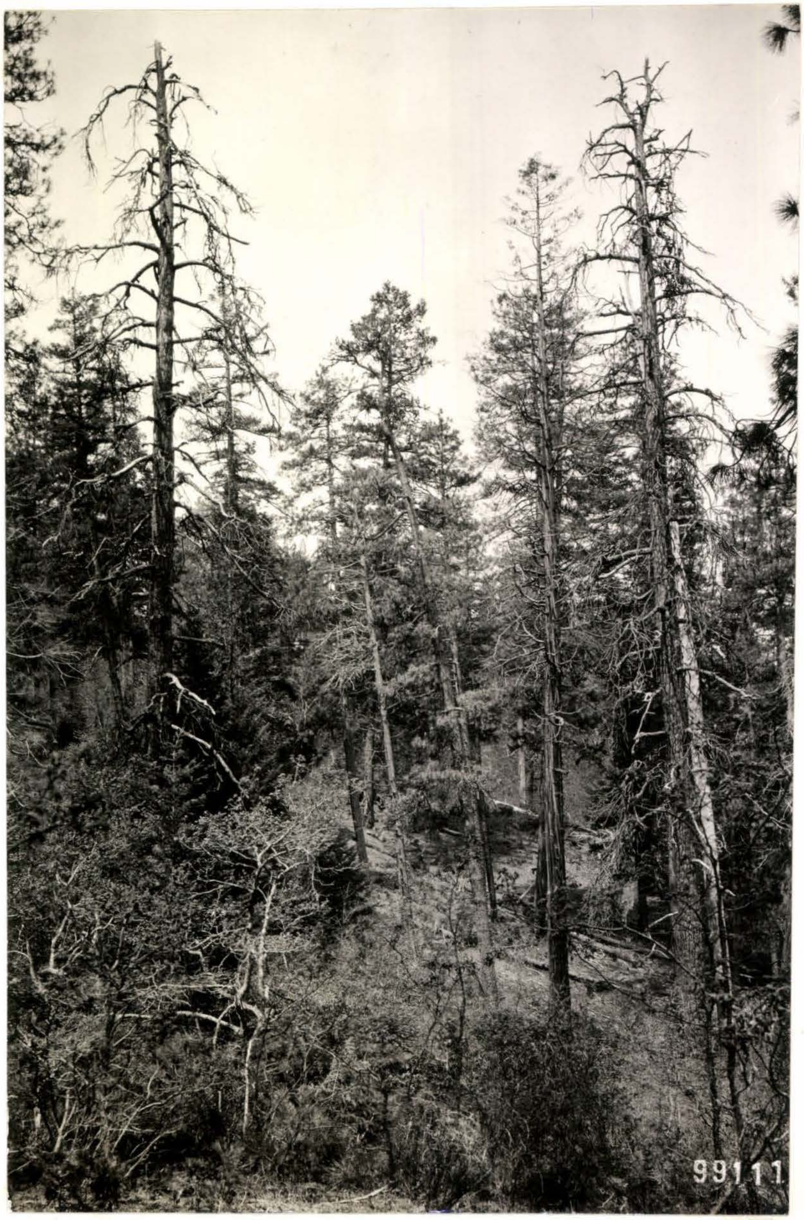


Stand of lodgepole pine killed by the mountain pine beetle in the Yosemite National Park: Epidemics of this character kill practically all of the mature timber within a comparatively short stands. They do not occur however in the mixed stands of yellow pine and sugar pine.

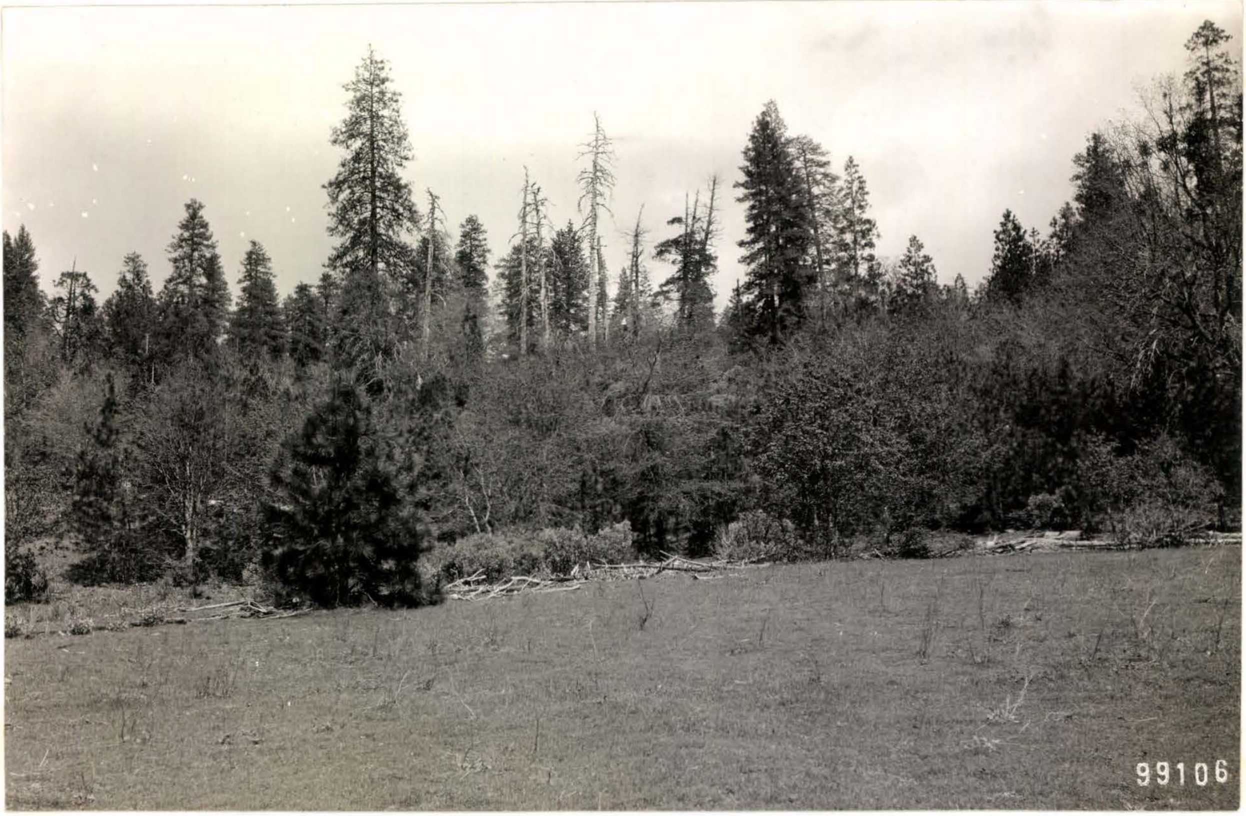




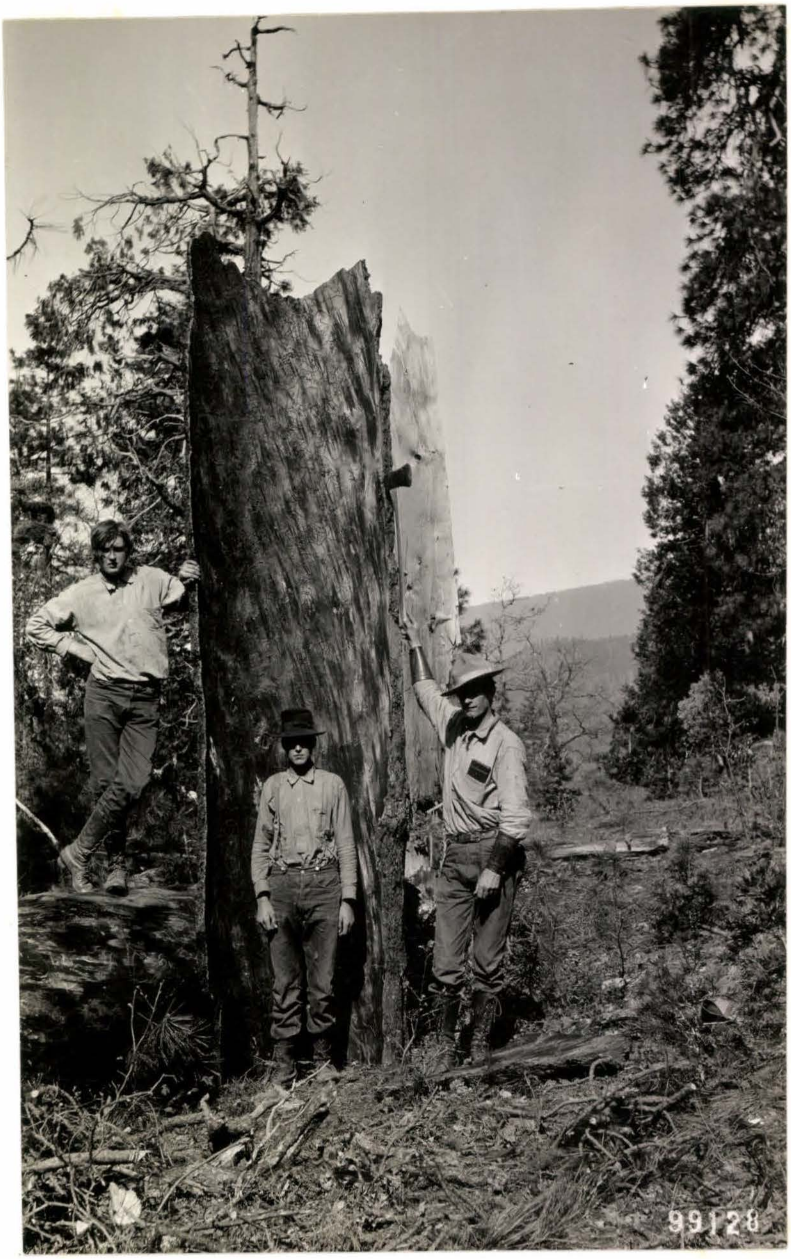
Two views in Tulare county, California, showing mature trees killed by the Jeffrey pine beetle on the Sequoia National Forest. The depletion of the forest from this cause is unmistakable.



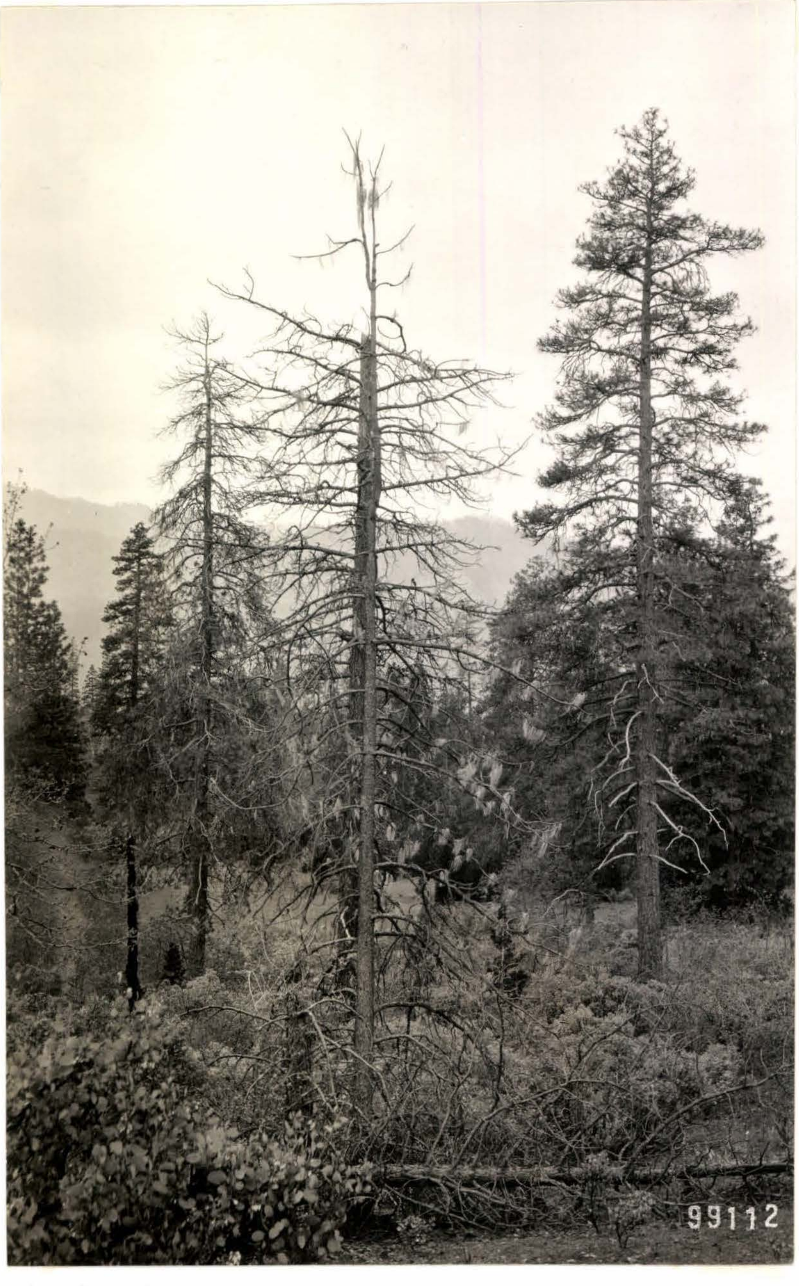
Insect Reconnaissance - Klamath National Forest, Cal. Barkhouse Project. May 1911. Black topped trees killed by Dendroctonus brevicomis. Lec.



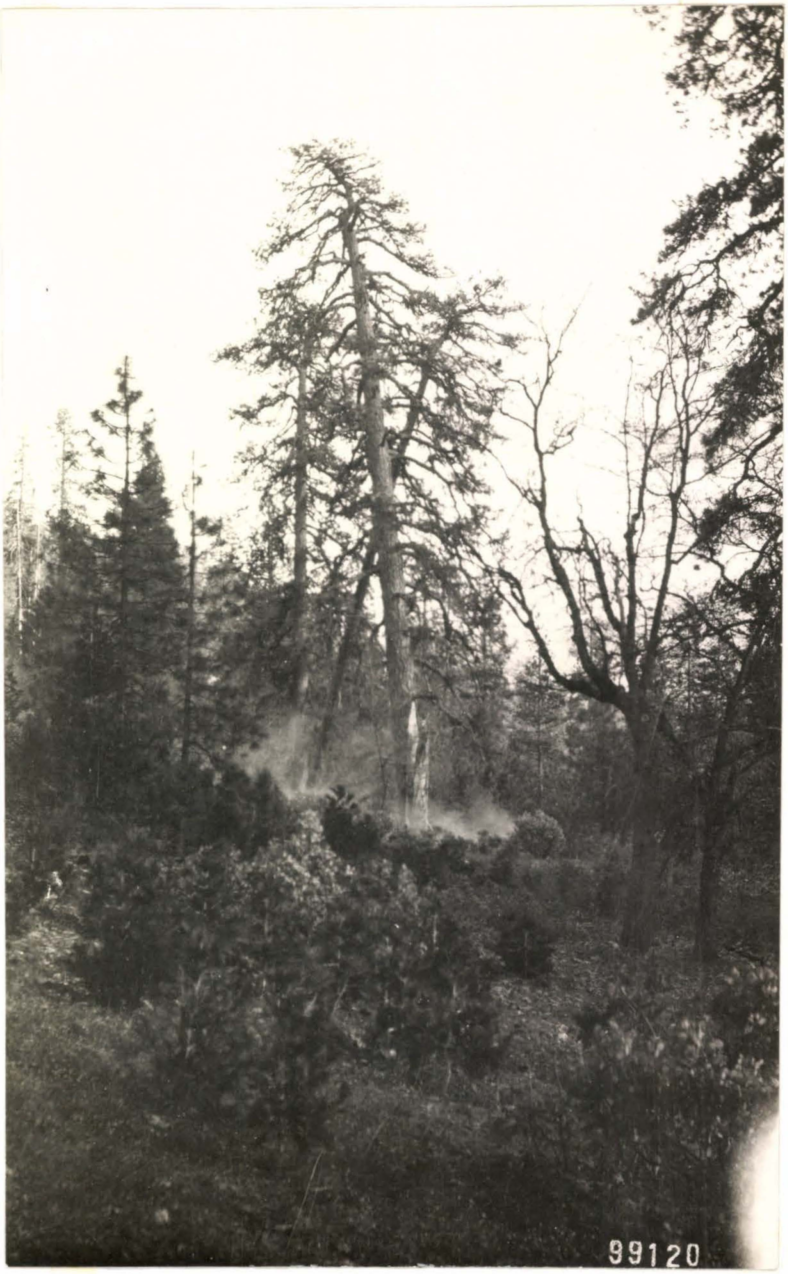
Insect Reconnaissance - Klamath National Forest, Cal. Barkhouse Project. May 1911. View from the Knudson field, Sec 17, Twp 46, N R 8 W, MDM. Showing accumulation of ghost trees which have been killed by Dendroctonus brevicomis.



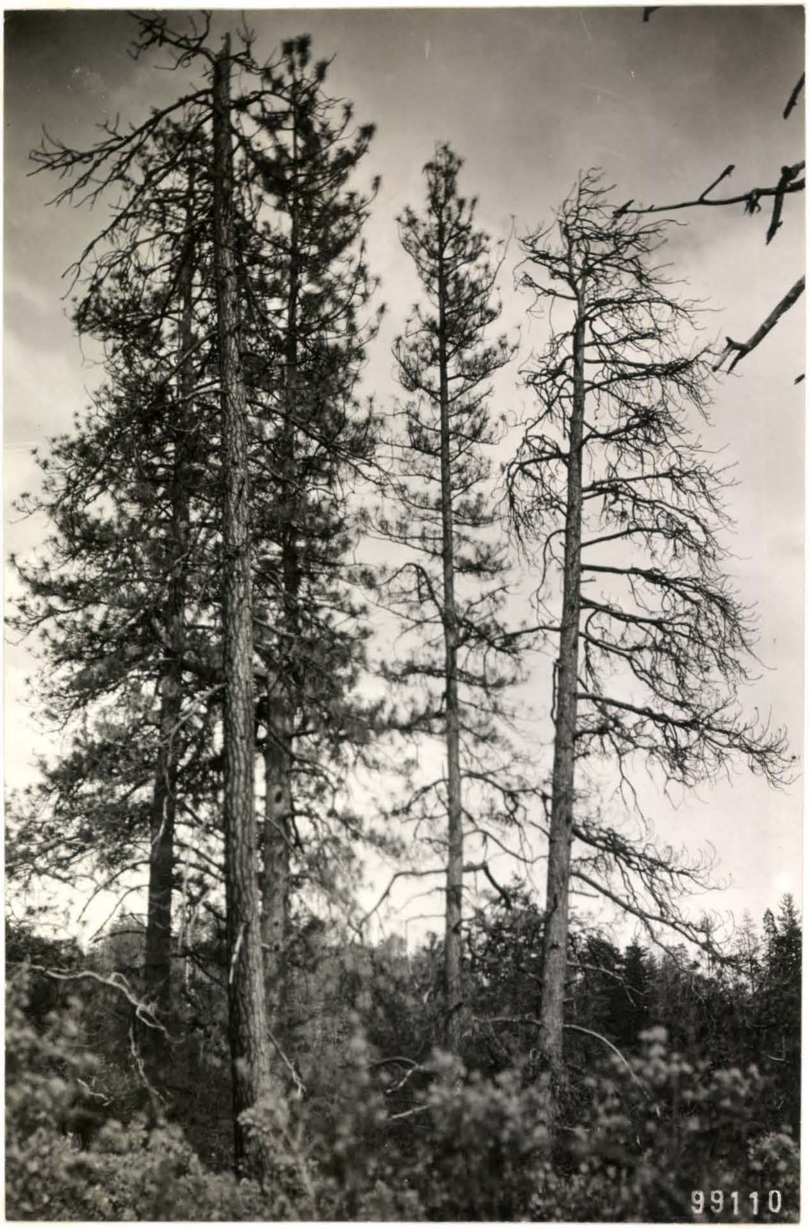
Insect Control - Klamath National Forest, Cal. May 1911. Barkhouse Project. Section of infested bark removed from tree.



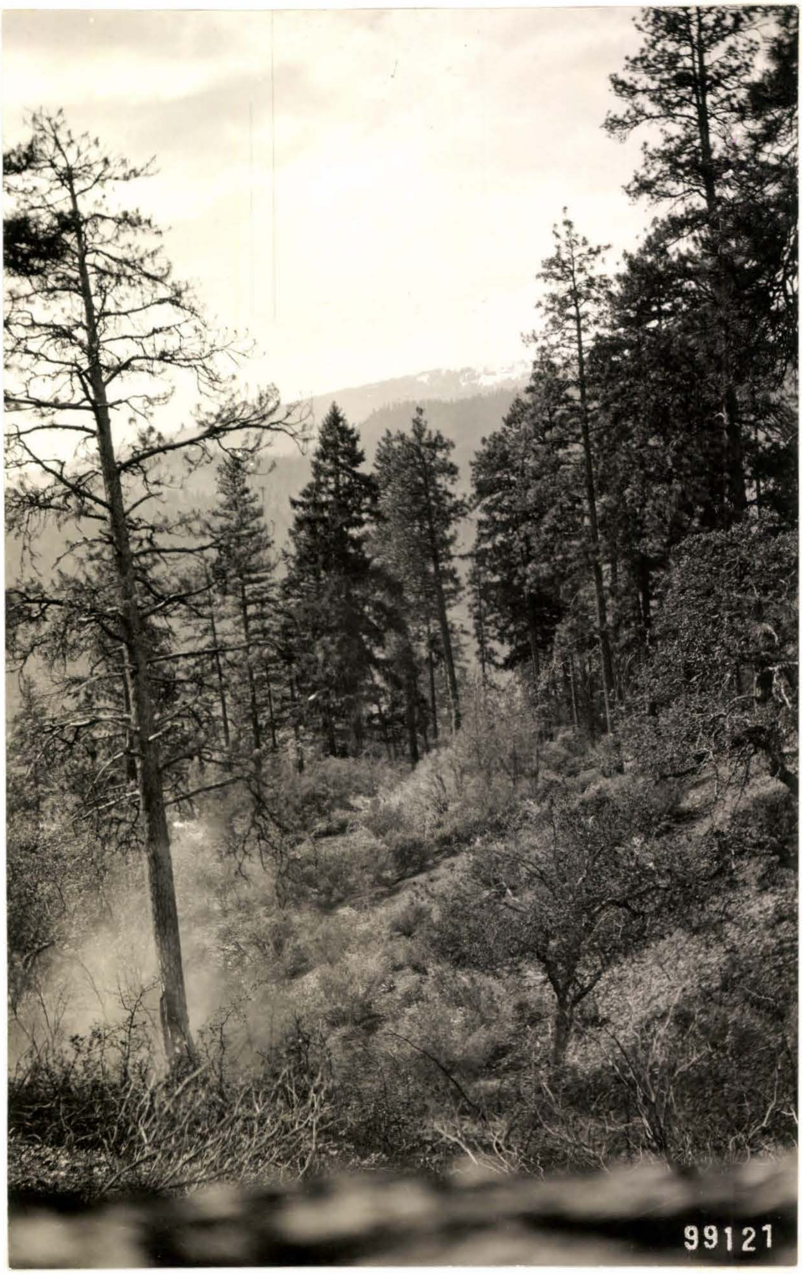
Insect Reconnaissance - Klamath National Forest, Cal. Barkhouse Project. May 1911. Black topped trees killed by Dendroctous brevicomis. Lec.



Insect Control - Klamath National Forest, Cal. Barkhouse Project, May 1911. Felling a 44 inch infested tree by the use of dynamite.



Insect Reconnaissance - Klamath National Forest, Cal. Barkhouse Project, May 1911. Black topped trees killed by Dendroctonus brevicomis.



Insect Control - Klamath National Forest, Cal. Barkhouse Project, May 1911. Felling an infested yellow pine tree by means of dynamite.